LYONS – MOORES CREEK ENHANCEMENT PROJECT

PREPARED FOR: MILLER CATTLE COMPANY

PREPARED BY: SPANISH PEAKS ENGINEERING & CONSULTING, LLC
WITH SUPPORT FROM LYNN BACON (TERRAQUATIC)
AND KARIN BOYD (APPLIED GEOMORPHOLOGY)

PREPARED ON: SEPTEMBER 2016

Photo – Existing Perched Reach of Moores Creek (Facing Downstream)

PROPOSED PROJECT DESCRIPTION & HISTORY

The limits of the reach of Moores Creek proposed for stream enhancements begin just downstream of the existing West Madison Canal undercrossing and end at the HWY 287 Culvert inlet at the east edge of the property. This particular portion of Moores Creek appears to have been straightened around 1950 (see photos below) to follow the existing driveway; after which a series of new trees were planted immediately adjacent to the stream, including a number of non-native fast growing willows which have since grown to an enormous size.

Moores Creek Photos through Subject Property in 1955, 1979, and 2015

Over time, the line of trees planted along Moores Creek have grown up and into the stream bed and have simultaneously acted as a large wind break and dust trap; as a result of the trapped dust and dropped organic matter from the trees, the stream bed has aggraded over time resulting in a perched stream condition along this reach. As a result of this perched stream condition, stream flows have spilled/seeped over to the adjacent pasture to the south, spreading out in places and and/or collecting into existing flood irrigation ditches and overflow channels. As this water has spread out across this field it has warmed and overlapped with livestock areas resulting in significant water quality degradation; including measured increases in sediments, nutrients, and even bacteria. As a result, this water shed has been deemed a priority for the Madison County and this reach of Moores Creek in particular identified for proposed stream improvements.

PROJECT GOALS & OBJECTIVES

The goal for this project is a design for Moores creek that will function as a healthier perennial stream, carrying sediment, with an accessible floodplain, supporting a diverse riparian plant community, and providing fish and wildlife habitat; all without significant mechanical manipulation in the future. Additionally, the channel, stream bank and upland conditions on the Lyons property should not contribute to sediment, nutrient, or e-coli concerns which have been identified on this stream in the past by MT DEQ and the Madison Conservation District.

DESIGN SUMMARY

To meet the project objectives, a design team was assembled with the diverse skills, training, and experience to complete the project. The team members included, Karin Boyd (geomorphologist), Lynn Bacon (professional wetlands scientist), and David Sigler (MS Civil Engineering, PE, TSP).

After the initial walk through by the design team, several alternatives were considered, including: no action, enhancement of the existing alignment, bumping in and out of the existing alignment, and building a new channel either north or south of the existing alignment.

The first step in the design process was to identify a reference reach. Between the limited space allowed for stream movement downstream and the addition of a reservoir upstream, it was determined that this stream system was in a state of transition; therefore, a historic restoration was not appropriate. Nonetheless the approximately 800' section of Moores creek extending from the West Madison Canal downstream to the culvert crossing at Moores Creek Road upstream was selected to be a reference reach for a more stable version of what this stream was transitioning into.

Photo – Reference Reach

The reach of river to be restored exists in a region of transition from a Rosgen Type "B" immediately downstream of the reservoir to a Type "C" stream at the Moores Creek Road crossing immediately upstream of the chosen reference reach for this project. The reference Reach is approximately 751 LF of stream over 592 LF of distance for an existing sinuosity of 1.27. The average bed grade across this distance is 1.13% (1.43% ground slope). Two representative cross-sections were taken through the Reference Reach (Sheet 15). Section "E" at existing station 20+50 had slope of 0.57%, an active channel width of 8.1', and a floodway width of 37' for an entrenchment ratio of 4.6 and a width to depth ratio of 14. Section "F" at existing station 23+50 had slope of 1.42%, an active channel width of 6.8', and a floodway width of 20' for an entrenchment ratio of 2.9 and a width to depth ratio of 20. Overall through this reach the active channel width varied between 5'-10', with a typical of 7', and the floodway varies between 20'-70'. These characteristics are consistent with a Rosgen Type "C" stream which typically has a moderate to high sinuosity (> 1.2); a moderate to high width to depth ratio (> 12); and slightly entrenched (> 2.2). The general description of a Rosgen Type "C" stream is as follows: "a low gradient, meandering point bar, riffle-pool, alluvial channels with broad, well-defined flood-plains."

Due to the lack of available wetland sod borrow areas on site, the project has been designed for top soil and a wetland seed mix along with nursery container stock plantings behind pre-established coir fabric wetland sod mats from North Fork Native (or similar). These approximately 3.2' wide by 16' long mats are placed over saturated top soils which are temporarily held in place by a cobble stone toe comprised of 2"-8" cobbles. The 2" gravels represent the maximum material size transported at bank-full (also the size of the riffle gravels); and the 8" max cobble size represents the existing maximum diameter (D-Max) identified in the reference reach.

STREAM GRADE AND PLANFORM DESIGN

The total length of reach under consideration for Moores Creek improvements extends from the downstream end of the existing West Madison Canal to the existing culvert invert at Highway 287 on the western property boundary. This is a total of 1773 LF of existing stream length over 1607 LF of distance with a grade drop of 17.0 feet resulting in an existing sinuosity of 1.1 and average grade of 0.96% (1.06% ground slope). For much of this distance the stream is perched above the adjacent ground elevations with a steep grade break to drop down to the existing culvert just before reaching Highway 287. The proposed design for this project includes some in-stream work at the upper end of this reach as well as new stream channel construction and alignment at the lower end of the project limits.

The purpose of the in-stream work is to begin dropping the existing stream thalwag and water surface to eliminate the existing stream seepage and spill off into the south pasture as well as to begin the process of balancing the grades throughout this reach. This work begins approximately 125 feet downstream of the existing canal undercrossing at existing stream station 17+14 and ending at station 12+94 where the new channel alignment begins for a total distance of 420 LF. The existing grade drop across this reach is 2.44’ for a slope of 0.58%; the proposed drop across this reach after the in-stream work is 3.87’ for a slope of 0.92%. The location of the star of this project also coincides with one of 3 proposed livestock crossing and grade control location, consisting of a 12” thick layer of cobble material capped by a 4” thick layer of 2” minus stream bed gravels. In addition to stream bed excavation, adjacent bank work will be completed as directed to lower the adjacent wetland banks to maintain their access to water and the stream's access to its adjacent floodway.

Below the in-stream restoration work begins the proposed new stream alignment and channel work starting at existing stream station 12+94 and ending at the existing stream culvert at highway 287 (station 0+68). The proposed new reach length will be increased from 1,226 feet to 1,382 feet over a distance of 1,125 feet for a proposed sinuosity of 1.23 (increased from 1.09 for the existing stream) and a new average grade of 0.77%. Both of these values are within the typical range for a Rosgen Type "C" Stream which is characterized by a moderate to high sinuosity (>1.2) and a grade between 0.1%-2.0%. The decision was made to move the new alignment to the north of the existing stream and row of mature trees in order to take advantage of the shade provided by these trees as well as to move the new alignment as far as possible from the existing pasture and source of contaminants.

Bouncing the stream in and out of the existing alignment and trees was deemed to be problematic in terms of preservation of the existing established vegetation and cost; in addition the new alignment presents an opportunity to enlarge the existing riparian corridor and habitat. A portion of the existing driveway is shifted to the north in order to maintain the new alignment north of the existing tree line for as far as possible and to take advantage of a large opening in the existing mature trees to pass through to the south before reconnecting with the existing stream alignment near the culvert at Highway 287.

CHANNEL CROSS-SECTION DESIGN

Channel cross-section design was approached by matching the existing upstream reference reach to establish floodway width (20'-70'); active channel width (5'-10' w/ 7' typical); entrenchment ratio (2.9-4.6); and width to depth ratio (14-20). As noted in the Design Summary above, the new alignment was designed as a "low gradient, meandering point bar, riffle-pool, alluvial channels with broad, well-defined flood-plains."

HYDROLOGY & HYDRAULICS

To complete the design of this project estimates needed to be made for the baseflow, bankfull (2-yr), 10-year, and 100-year stream flows for this reach of Moores Creek. The baseflow estimate of 3 cfs is based upon the streamflow measurements provided by the Madison County Conservation District; and the bankfull estimate of 16.5 cfs is based upon the maximum flow that can pass under the existing West Madison Canal before spilling into the canal itself and compared it to bankfull estimates made by the NRCS (Attachment No.1). For the 10 year and 100 year estimates, a hydrological analysis was performed based upon a weighted average of the basin characteristics and the active channel width (see Attachment No.2). The results of these analysis are as follows:

- Base Flow: 3.0 cfs
- Bank Full (2 Year Peak Flow): 16.5 cfs

- 10 Year Peak Flow: 152 cfs (from weighted average of Basin Characteristics & Active Channel)
- 100 Year Peak Flow: 408 cfs (from weighted average of Basin Characteristics & Active Channel)

The estimated 10 year and 100 year flows do not take into account the storage effect of the reservoir above this project. As a result, it is anticipated that the baseflow and ordinary high water flows will be the most consistent, while the larger flows are stored and moderated by the reservoir resulting in more steady, clear (sediment free) downstream flows.

PROJECT SPECIFICATIONS

Stream Bed Gravels:

Stream bed gravels in proposed riffle reaches of the new Moores Creek stream alignment shall be 2" minus rounded gravels based upon observed gravels in the existing channel and irrigation ditches across the existing pasture to the south. This material size was further confirmed based upon the incipient mobility shear stress calculations completed by Karin Boyd of Applied Geomorphology (Attachment No.4), with particle sizes between ¾”-1 ½” (17-41 mm) mobilized at the bank full (2 year) flows.

Cobble Toe:

Cobble Toe material shall be approximately 800 cy of 2-8 inch cobble sourced and screened from Alder Gulch tailings. This toe material will confine the topsoil under the coir fabric wetland sod mats and shall extend as follows: 24” below the stream bed at high energy regions (riffles & outside bends), 8"-12" in low energy reaches (glides, inside bends, etc.), and to the bottom of all pools. Toe material was sized based upon the maximum diameter (dmax) cobble material identified on the stream bed of the existing reference reach. This material size was further confirmed based upon the incipient mobility shear stress calculations completed by Karin Boyd of Applied Geomorphology (Attachment No.4), with particle sizes between 1”-5” (20-117 mm) mobilized at the 10 year estimated flows.

Live Sod Coir Fabric Mats:

Live sod mats shall be from North Fork Native Plants or approved equal and shall be wrapped in a biodegradable, processed fiber plugged with a wetland plant species mix that includes Nebraska sedge, wooly sedge, and Baltic rush. The mats shall be placed over lightly compacted and damp top soils at or just above the active channel water surface elevation. They shall be staked with 8-12 16" wooden stakes per 3.2'x16' mat. The stakes shall be driven at a slight angle with about 4" of the stake protruding above the mat. These matts and the upland seeding behind them will be placed after spring run-off to allow sufficient time for establishment before the next season’s peak flows. With good soil to root contact with the sod mats, root establishment should take place within 2 weeks. Additionally, the maximum calculated shear stress of 1.2 psf for the 10 year stream flow along Reference Cross-Section No.2 is less than the allowable shear stress of 4 psf for this fabric.

Riparian Planting:

The riparian plants shall extend across both Zone 1 (overbank floodplain benches) and Zone 2 (upland from the toe of the Zone 1 benches to the matched existing grade). The Zone 1 riparian plantings shall consist of a mix of the following native species: Sandbar/Coyote Willow (Salix Exigua) @ 50%-60%; Geyer (Salix Geyer), Booth (Salix Booth), and Bebb (Salix Bebbiana) willows at 20%; Red-Osier Dogwood (Cornus Sericea) @ 10%; Goden Currant (Ribes Aureum) @ 10%-15%; and Thin Leaf Alder (Alnus Incana) @ 10%. The Zone 2 riparian plantings shall consist of a mix of the following native species: Ggolden Currant (Ribes Aureum); Narrowleaf Cottonwood (Populus Angustifolia); Black Cottonwood (Populus Blsamifera Var. Trichocarpa); Silver Buffalo Berry (Eleagunus Commutate); Chokecherry (Prunus Virginiana); and Aspen (Populus Tremuloides).

The minimum riparian planting schedule is as follows:

- Willow stem tube-lings on a minimum density of 1 stem per running bankline foot on outside bends and cross-overs and one stem per 2 feet of running bankline elsewhere.
- 1 Gallon potted plants at a density of 1 plant per 4 feet of running bank line foot on outside bends and cross-overs and 1 plant per 8 feet of bankline elsewhere.
- 5 Gallon potted plants at a density of 1 plant per 6 feet of running bankline foot on outside bends and cross-overs and 1 plant per 12 feet of bankline elsewhere.
- 10 Gallon potted plants or transplanted mature willow clumps at a density of 1 plant per 24 feet of bankline, concentrated on outside bends in strategic clusters.

COST & QUANTITIES ESTIMATE

The existing channel work is estimated to be completed with a single track excavator, plus dump truck, support backhoe, laborer and foreman with an estimated crew hour cost of $280 / hour. This work is anticipated to progress at 10 LF / hour for total cost of $28 / LF or
$11,760 for the entire 420 LF stretch.

The new channel work is estimated to be completed with a single track excavator, two dump trucks, a support backhoe, 2 laborer's, and a foreman for total cost of $360 / HR for the rough grade, which is anticipated to take 7 days including clearing and grubbing (200 LF / day). This work will be followed by placement of the cobble toe which is estimated to take 3 days with an excavator, dump truck, backhoe, foreman and laborer ($280 / crew hour) and 800 CY of cobble gravels estimated at $32/CY plus one day to place the riffle gravels and 120 CY of material at $24/CY. The top soil is an estimated $16/CY placed (800 CY$) plus $0.12/SF for ½ are of hydroseed, and wetland sod mats delivered and set are an estimated 12/LF (2,800 LF). All in the estimated new stream work is $104,000 for 1,380LF ($77/LF).

The proposed new riparian vegetation is estimated at $3 / Tubeling, $12 / 1 Gallon Plant, $26 / 5 Gallon Plant, and $40 / 10 Gallon Plant installed for a total Riparian Landscaping Estimate of $25,000 to plant and $5,000 to cage and protect.

The livestock crossings (3 each) are an estimated $1,200 each.

The existing pond excavation of 500 CY to maintain its depth with the reduced design water surface is estimated at $10 / CY; while the estimated cost for the optional pond expansion of 2,000 CY is $5 / CY.

The total of the above estimates is $150,000 for the stream work, including livestock crossings plus $5,000 for the existing pond excavation and $10,000 for the pond expansion. The estimated markup for Overhead, Profit & Contingencies is $30,000 (18% of $165,000).

PROJECT DESIGN DELIVERABLES:

1. NRCS Practice Standard 582 for Open Channel Conservation Practices was reviewed and is attached along with the TSP-2 Form signed by the landowner (Attachment No.5).

2. The TSP (Sigler) made an initial site visit to visit with the client and collet design information.

3. The TSP (Sigler) prepared and/or engaged a qualified person to complete the following:

    a. Narrative Design Report: See the above sections entitled Proposed Project Description and History, Project Goals & Objectives, Design Summary, and Stream Grade and Planform Design to find the executive summary, design objectives, design references & reference reach, assumptions, design alternatives considered, and construction methods and materials.

    b. Survey Data: As noted in the Construction Drawings, the Moore’s Creek job was surveyed using RTK GPS, with the base station set up over CP1. The coordinates for the control points at the Moore’s Creek site were established by referencing our measurements to a control point which has a known WGS84 Latitude and Longitude, and Ellipsoid height. This job used a local coordinate system rotated to True North and anchored at CP1 which was assigned the state plane coordinates for that position. The elevation datum for this survey is NAVD 88 computed using the Geoid 12A model. Included in Attachment No.6 is a list of the Control Point Coordinates as well as a summary of the staking coordinates, grades, and offsets for the proposed thalwag, stream bead, top of bank (TOB), floodplain bench toe, and grade match point.

    c. Soils: Included in the Moore’s Creek Restoration Project Aquatic Resources Delineation Summary Report by Lynn Bacon of TerraQuatic (Attachment No.7) is copy of the NRCS Soils report as well as a summary of the results of the onsite evaluation completed including soil sample pits taken. Construction limitations identified for use of the on-site soils are characterized by the report above, including the anticipated lack of available stream bed gravels for the proposed riffle reaches, necessitating imported materials.

d. Open channel information including reach and reference reach characterization, stream channel design shear stresses, and calculations for bed load and sediment transport competency and cobble toe sizing for temporary protection were provided by Karin Boyd of Applied Geomorphology (Attachment No.4). Characterization of the stream channel before and after the project in the form of hydraulic calculations at four cross-section locations are included in Attachment No.3, which also demonstrate that the proposed changes will not increase the base flood elevation (BFE) for the required Floodplain Development Permit. Stream Channel layout coordinates showing station, feature, and design grades are included with the Survey Data in Attachment No.6.

e. Other Design Requirements: The project as designed will balance / reduce the average grade along this reach, which will reduce the stream velocity from the existing condition which involves a steep grade drop right before the culvert. Between the decreased velocity and the adjusted alignment which approaches the culvert laterally, the erosive potential should be decreased thereby creating no adverse impacts to the proposed county road culvert project.

f. Estimated quantities for the project are summarized on Sheet 1 of the Plan Set and estimated costs for these quantities on this project are included in the Cost & Quantities Estimate above.

g. Construction and Material Specifications: Items of work and construction details specific to the job, including testing protocols are included in Sheet 2 of the Construction Plan Set.

h. Construction Inspection Plan: The critical construction and material items that require inspection along with required submittals, qualified inspectors, schedule of critical construction items, safety details, and construction tolerances are included in Sheet 2 of the Construction Plan Set.

i. Operation and Maintenance Plan: The Operation & Maintenance Plan including critical inspection items and frequencies, maintenance procedures, and relevant contact information is included in Sheet 2 of the Construction Plan Set.

4. To the best of my professional knowledge, judgment, and belief, the Construction Plan Sheets meet the intent of NRCS Practice Standard 582. This Plan Set includes the following drawings:

Sheet 1 – Cover Sheet
Sheet 2 – General Notes
Sheet 3 – Survey Control & Staking
Sheet 4 – Project Overview (Aerial)
Sheet 5 – Project Overview (Topo)
Sheet 6 – Wetland Delineation (Aerial)
Sheet 7 – Wetland Delineation (Topo)
Sheet 8 – Project Design Overview (Topo)

Sheet 9 – Design Reach No.1
Sheet 10 – Design Reach No.2
Sheet 11 – Design Reach No.3
Sheet 12 – Cross-Section “A” (Typical Glide) & Cross-Section “B” (Typical Pool)
Sheet 13 – Cross-Section “C” (Typical Riffle) & Cross-Section “D” (Typ. In-Stream)
Sheet 14 – Cross-Sections “E” & “F” (Reference Reach)
Sheet 15 – Project Profile – Existing
Sheet 16 – Project Profile – Proposed

5. A Completed Construction Specifications Cover Sheet MT-ENG-7; rev 2/11) will be provided to the landowner to be signed and dated.

PROJECT PERMITS

Permits required for this project, include: a 310 Permit from the Ruby Valley Conservation District; a 404 Permit from the Army Core of Engineers; a 318 Authorization from the Department of Environmental Quality (DEQ); a Notice of Intent (NOI) from the DEQ; and a Floodplain Development Permit from Madison County (Map No. 3000440003E).

PRECONSTRUCTION REQUIREMENTS

1. The TSP shall personally conduct a pre-construction conference with the landowner and contractor to ensure that they both understand the plans and specifications; that all the required permits and permissions have been acquired to construct the project; that utility locates have been notified; and that to the best of the tsp's knowledge, all other relevant rules and regulations are being adhered to for the construction of this project.

2. Utility information shown on the drawings is approximate and may be incomplete. For accurate location contact, prior to excavation, the utilities underground location center at: 1-800-424-5555. Contractor to be aware of overhead lines in the project vicinity and use the utmost care at all times around the lines.

PROPOSED CONSTRUCTION METHODS

The proposed project involves a reach of in-stream enhancements as well as a reach of newly constructed channel. The existing channel improvements include excavation of the existing channel down up to 18” along with lowering of the adjacent banks in order to maintain water contact as well as floodplain connectivity. Lowering of the adjacent banks involves the removal of existing sod, excavation of the subgrade below the sod, and re-setting of the live sod back in place.

The new channel work involves excavation of a new stream channel prism including bed, banks, and adjacent floodplain; followed by the placement of stream bed gravels in the riffle reaches, construction of new bank lines and the planting of new riparian vegetation and wetland grasses in the new adjacent floodplain deck. Due to the lack of wetland sod borrow sites on this project, the new bank line will be constructed with cobble toe material used to confine new topsoil behind it. Over this topsoil along both sides of this bank line will be placed a 3 foot wide imported wetland sod matt. The topsoil behind this matt and extending across the limits of the floodplain bench will be seeded with a wetland seed mix.

The proposed construction sequence for this project is as follows:

1. New alignment rough excavation to average bed grade, floodplain benches and slopes to match points.
2. Toe installation using keyed cobble stone toe trench material to build sub grade for outside bank lines.
3. Place gravel bed material in riffle sections.
4. In-stream excavation and redirection of stream into new channel.
5. Final bed grade-pool excavation/controls/bar grading
5. Place and lightly compact topsoil above and behind cobble toe material.
6. Plant new nursery riparian stock material and cage plants as required.
7. Seed new topsoil areas with approved wetland seed mix and cover with a mulch.

This construction sequence is a recommendation only and ultimately the sole responsibility of the contractor.

CONSTRUCTION INSPECTION

Consistent with the project design, the construction inspection plan for this project includes the following:

1. Critical inspection area and materials.
   a) Imported cobble adequately approximates the target 2-8” gradation.
   b) Installation of cobble toe to typical depths and width described in the drawings.
   c) Plant material is healthy as installed.
   d) Coir mat wetland sod mats are set on properly prepared subgrade and staked per the manufacturer's recommendations.
   e) The adjacent inset benches are lowered to appropriate elevations along the in-stream excavation area.

2. Tolerances for lines and grades:
   a. Average rough grade pass excavation within 0.2' of the stakeout grade based on 100 foot segments as measured at constructed riffle crest/tailout locations.
   b. Final grade - fit in field.
   c. Plan view/limits of excavation per fit in field based on average dimensions staked per typical sections in the drawings.

3. Compaction
   a. No compaction testing of soils is required on the project; compaction will be tracked Based upon appropriate compactive effort.
   b. Bank toe cobble will be bucket packed.
   c. Bank face sod will be bucket tamped.

OPERATION & MAINTENANCE

1. O&M General
   a. A representative of the design team and/or miller family will inspect channel daily during runoff events in year 1 and as needed after year 2.
   b. If inspections warrant, temporary measures may be taken to mitigate any unexpected as-built channel behavior.
   c. Following runoff an inspection will be made to determine if any further action is warranted to protect the integrity of the channel form and if so, those measures implemented.

2. O&M Channel Re-Alignment

The new channel alignment will not be diverted through the use of a plug or any other in-stream or wetland fills, but rather via the excavation down of the existing channel at the top of the project to re-direct flows which are currently spilling into the field to the south. Annual inspections for the first 3 years after spring run-off are recommended to ensure the new alignment remains active

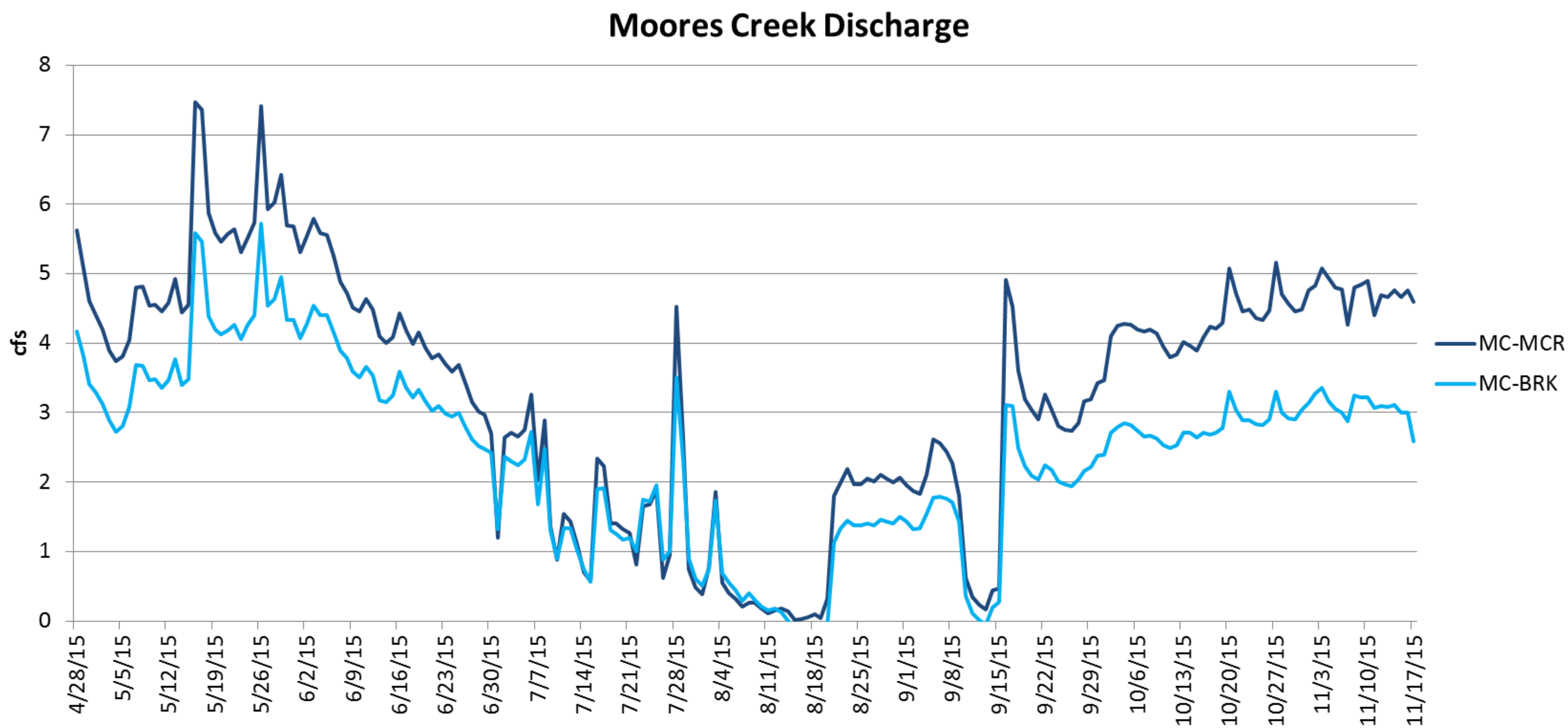
3. New riparian seeding mix shall be covered and monitored weekly for the first 3 months, then monthly for the next 12 months to ensure it stays wet and covered; and new nursery stock plants shall be monitored to ensure the cages are effective or whether supplemental measures are required.

LYONS – MOORES CREEK ENHANCEMENTS

Ennis, MT

Attachment No.1

Moores Creek Hydrology
(Baseflow & Bankfull Estimates)

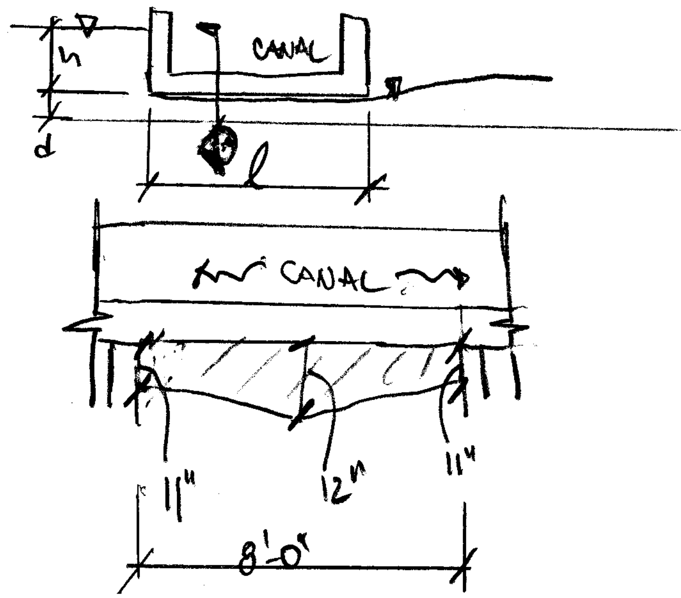

Moores Creek Discharge
cfs
0
1
2
3
4
5
6
7
8
4/28/15
5/5/15
5/12/15
5/19/15
5/26/15
6/2/15
6/9/15
6/16/15
6/23/15
6/30/15
7/7/15
7/14/15
7/21/15
7/28/15
8/4/15
8/11/15
8/18/15
8/25/15
9/1/15
9/8/15
9/15/15
9/22/15
9/29/15
10/6/15
10/13/15
10/20/15
10/27/15
11/3/15
11/10/15
11/17/15
MC-MCR
MC-BRK

LYON'S - MOORES CR. REST. 7/20/2016 DAVID SIGLER, PE

PROJECT: 16185 SPANISH PEAKS ENG & CONS, LLC

MAXIMUM FLOW CALCULATION UNDER CANAL

* WATER HEAD HEIGHT (h) LIMITED TO DEPTH BEFORE SPILLING OVER BANK AND INTO CANAL DOWNSTREAM



- $h = 5013.46 - 5010.88 = 2.58'$
- $l = 14.0'$

$$S_0 = \frac{h}{l} = \frac{2.58}{14.0} = 0.1843$$

MANNING'S FLOW

$$V = \left(\frac{1.49}{n}\right) R_h^{2/3} * S_0^{1/2}$$

* $n = .025$ MIN. (0.30 - NORMAL) - GRAVEL BED (.014 UNFINISHED CONCRETE)

* $R_h = \frac{A}{P_w} = \frac{8' * 11.5/12'}{[8' + 11.5/12 * 2]} = 0.77'$

$$\rightarrow V_{MAX} = \left(\frac{1.49}{0.25}\right)(0.77)^{2/3}(0.1843)^{1/2} = 2.2 \text{ FT/SEC}$$

$$Q = VA = 2.2 \text{ FT/SEC} * 8'(11.5/12') = $$ 16.5 CFS MAX CHANNEL CAPACITY

* MEASURED FLOWS RANGE FROM 0.5 CFS - 7.5 CFS (7.5 CFS MAX MEAS. ON 5/19/2015)

** NO EVIDENCE OF SCOUR AT CANAL UNDERPASS CROSSING

David Lyons-Estimated Qbkf Summary:

METHOD	**Qbkf (cfs)**	**Notes:**
USGS WRIR 03-3408 Regression Equations:		
Basin Characteristics (BC)	68	SW Region DA=30 sq. mi. %DA above 6000' = 69.8 There is an irrigation diversion in Sect 1, T6N, R2W. Approximately 27 sq. mi. of the drainage area (90%) is ABOVE this diversion. This could have a significant effect on the Qbkf estimate using the BC regression equation. (See Water Rights Query System doc file for more details.)
6' Active Channel Width (AC)	15	Visual estimate of AC
8' Active Channel Width (AC)	26	Visual estimate of AC
Weighted BC + 6' AC	24	
Weighted BC + 11.9' Bankfull Width (BW)	34	This BW was ASSUMED to be at the low bank elevation from the surveyed riffle section. This elevation is 5024.54 and was much higher than the Qbkf elevation from visual indicators. The Qbkf elevation from visual indicators was 5023.04.
Weighted BC + 7.7' Bankfull Width	20	This BW was from visual indicators. Qbkf elevation = 5023.04.
Manning's Equation at Surveyed Riffle Section:		
Qbkf Elevation=5023.04 s=0.0025	10-12	The bankfull elevation and slope from visual indicators. The Qbkf slope of 0.0025 is less than the average channel slope of 0.0073. I would expect that the Qbkf slope would be similar to the average channel slope.
Qbkf Elevation=5023.04 s=0.0073	16-20	The bankfull elevation from visual indicators; the bankfull slope is the average channel slope surveyed on 9-22-2015 (TOR-TOR).
Qbkf Elevation=5024.54 s=0.0073	80-100	This Qbkf was ASSUMED to be at the low bank elevation from the surveyed riffle section and was much higher than the Qbkf elevation from visual indicators (5023.04). The Qbkf slope is the average channel slope (TOR-TOR). These flows seem very high.
Culvert Flow at Moores Creek Bridge	20	This bridge is just upstream from the surveyed riffle section. Flow was estimated using the "high water mark" on the culvert.

Qbkf from Regression Equations: $Qbkf=Q2(Q2/Q5)^{0.52}$.

NOTE: All elevations in this document are from the original csv survey files; before the OPUS correction.

Computation Sheet

NRCS–ENG-523A Rev. 6-2002

U.S. Department of Agriculture
Natural Resources Conservation Service

State	Project		
MT	David Lyons Open Channel		
By: MWZ	Date: 9/2015	Checked by:	Date:	Job No.:

Subject: Estimated Qbkf from Riffle Section — Sheet 1 of 5

Notes: 1) Sections/profile were done between Moore's Creek culvert crossing bridge and the Madison canal crossing, approx. 400' upstream of the canal.

2) Qbkf elevations were very hard to determine visually, but an attempt was made to do so.

Riffle Section @ STA 86.7 Qbkf = 5023.04

Qbkf slope was visually estimated and using CADD.

$$Q_{bkf} \text{ slope} = \frac{0.305}{122} = .0025 \text{ FT/100 FT}$$

From CADD:

Area = 6.58 FT^2 WP = 8.5 FT

R = 6.58/8.5 = .774 FT

Top width = 7.72 FT
d_{max} = 1.2 FT
Qbkf d_{mean} = 0.85 FT

Manning's n:
Using Ref. Table 3.1 HEC-RAS Hydraulics Reference manual.

n .035 - .045

$$Q = A \frac{1.486}{n} R^{2/3} S^{1/2}$$

$$Q = \frac{0.412}{n}$$

n	Flow (CFS)
.035	11.8
.04	10.3
.045	9.16

Computation Sheet

NRCS–ENG-523A Rev. 6-2002

U.S. Department of Agriculture
Natural Resources Conservation Service

State		Project		
By	Date	Checked by	Date	Job No.
Subject				Sheet 2 of 5

The Average channel slope (TOR-TOR) in this reach was measured to be

$$\frac{0.8'}{109.7'} = .0073 \text{ FT/FT}$$

STA	ELEV
28.8	5022.2
138.5	5021.4

I would expect the Qbkf slope to closely resemble the average channel slope in this reach. Since Qbkf indicators were hard to determine, estimate Qbkf flow using Average channel slope of .0073FT/FT

$$Q = A \frac{1.486}{n} R^{2/3} S^{1/2}$$

keep same WS elevation from previous — just change slope.
Area = 6.58 ft²
WP = 8.5 ft
R =

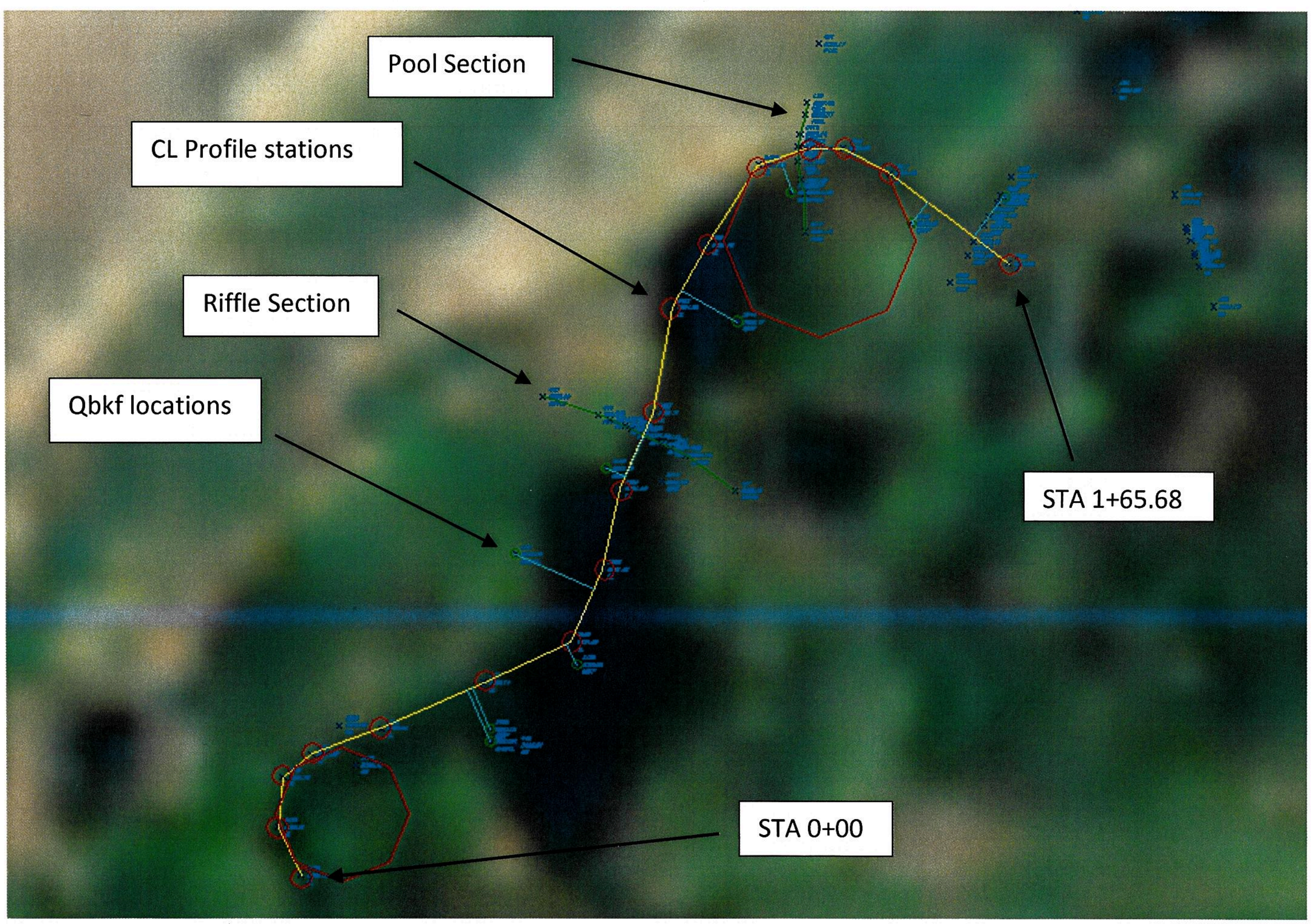
$$Q = \frac{.704}{n}$$

n	Flow (CFS)
.035	20.1
.04	17.6
.045	15.6

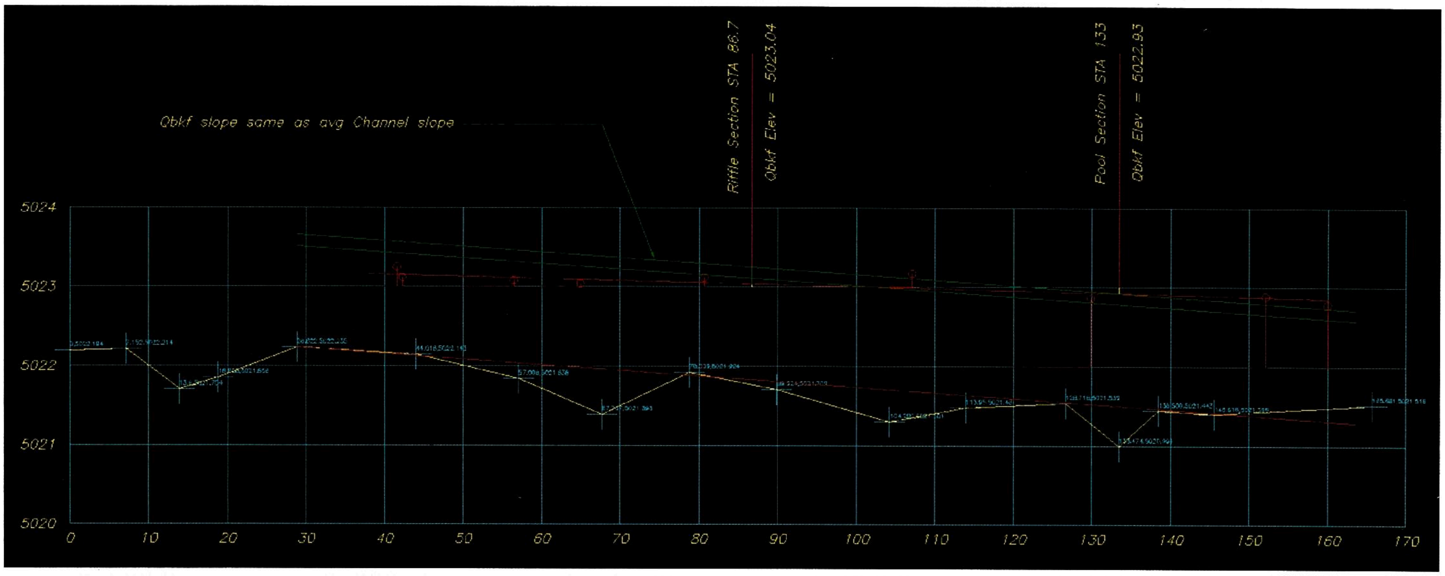
Qbkf 15-20 CFS

Estimate of Qbkf:

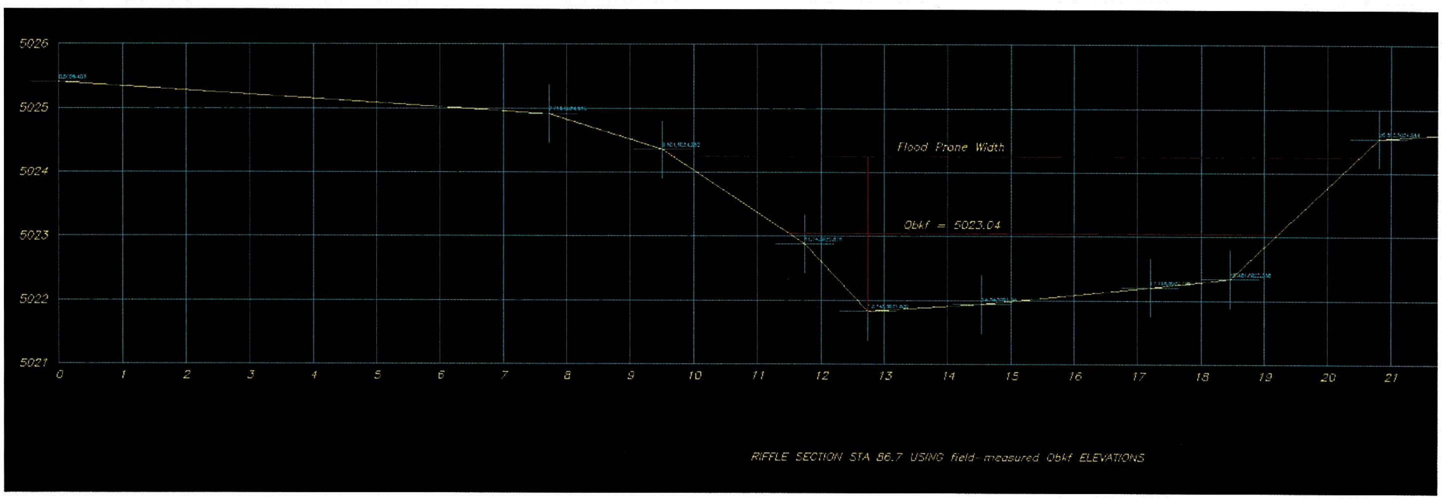
Area used for profile and sections:



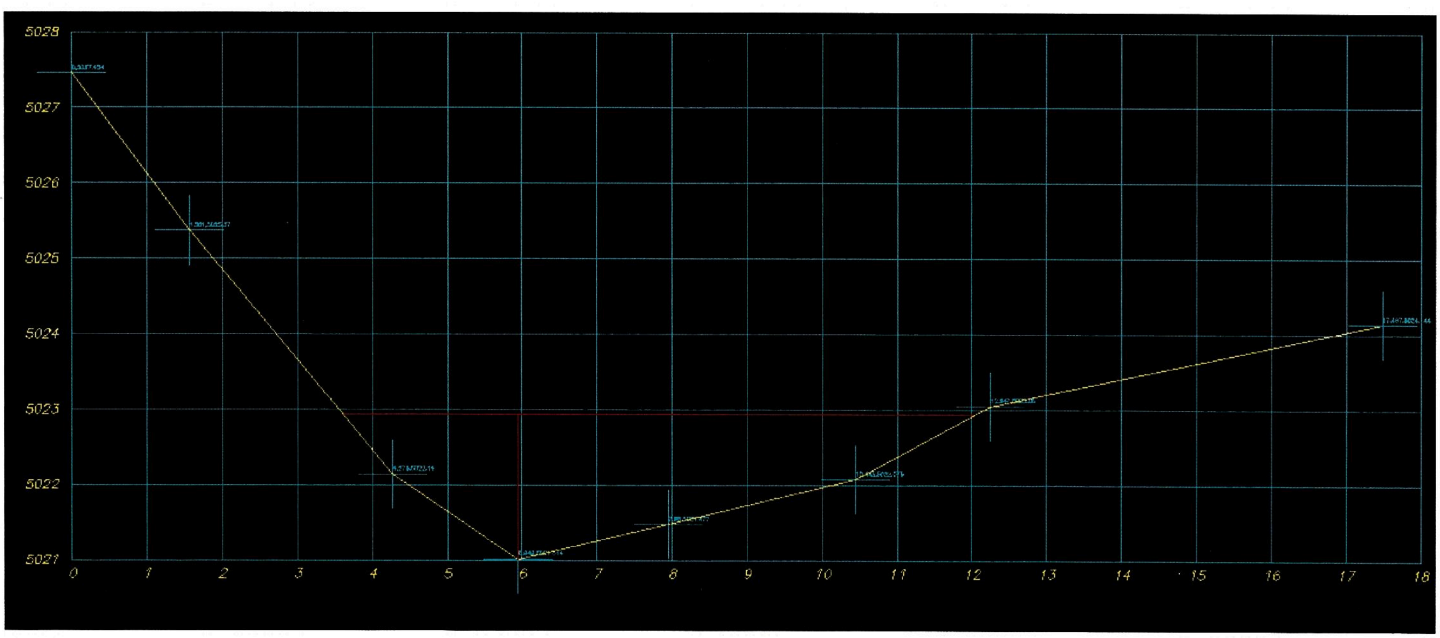
Profile:



Riffle Section:



Pool Section:



X	Y	profile STATION	ELEVATION
1448324.690	16470664.970	0.000	5022.194
1448321.685	16470671.460	7.152	5022.214
1448322.299	16470678.180	13.900	5021.704
1448326.173	16470681.270	18.855	5021.856
1448335.524	16470684.720	28.822	5022.235
1448349.415	16470690.880	44.018	5022.143
1448361.299	16470696.340	57.096	5021.838
1448365.491	16470706.120	67.737	5021.393
1448367.884	16470716.930	78.809	5021.924
1448372.370	16470727.100	89.924	5021.709
1448374.933	16470741.230	104.285	5021.301
1448379.644	16470749.670	113.950	5021.480
1448386.591	16470760.380	126.716	5021.539
1448392.963	16470762.630	133.474	5020.994
1448397.998	16470762.660	138.509	5021.443
1448404.239	16470759.260	145.616	5021.396
1448420.313	16470747.250	165.681	5021.516

- CL (Thalweg) profile from upper reach between Moore's Creek Culvert bridge and the Madison Canal Crossing

Qbkf Elevations:

STATION	ELEV	
41.6	5023.25	Right
42.3	5023.12	Right
56.5	5023.08	Right
65.0	5023.04	Left
80.7	5023.12	Left
107.1	5023.17	Right
129.9	5022.86	Right
152.1	5022.89	Right
160.0	5022.79	Left

Riffle Section STA 86.7 Qbkf ≅ 5023.04

David Lyons:
Moore Creek flood frequency (USGS WRIR 03-4308):

Southwest Region Basin Characteristics (CADD): Drainage Area = 30 sq. mi. %DA above 6000 feet = 69.8. Active channel width was visually estimated during the 6-11-15 site visit at a few locations.

RETURN INTERVAL	Basin Characteristics		6' Active Channel Width		8' Active Channel Width		Weighted-Basin Characteristics & 6' Active Channel Width	
	Flow (cfs)	SEP (%)	Flow (cfs)	SEP (%)	Flow (cfs)	SEP (%)	Flow (cfs)	SEP (%)
Q2	92	90.9	24	60.9	39	60.4	37	50.6
Q5	167	75.9	58	57.7	87	57.1	86	48.0
Q10	227	72.6	91	63.4	132	62.7	134	51.5
Q25	314	72.0	145	74.0	203	73.1	216	58.5
Q50	388	73.5	196	83.0	269	82.0	292	63.0
Q100	469	76.0	258	92.3	346	91.1	378	67.9
Estimated Bankfull Flow (cfs)								
Q_{bkf}	68		15		26		24	

ASSUME the Qbkf Elevation is at the LOW BANK ELEVATION on the Riffle Section surveyed on 9-22-2015. Bankfull Width = 11.9 feet (CAD section).

RETURN INTERVAL	Basin Characteristics		6' Active Channel Width		8' Active Channel Width		Weighted-Basin Characteristics & 11.9' Bankfull Channel Width	
	Flow (cfs)	SEP (%)	Flow (cfs)	SEP (%)	Flow (cfs)	SEP (%)	Flow (cfs)	SEP (%)
Q2							51	57.7
Q5							110	52.3
Q10							164	54.6
Q25							252	59.7
Q50							330	64.1
Q100							416	68.6
Estimated Bankfull Flow (cfs)								
Q_{bkf}							34	

Manning's: Q=A(1.486/n)R^0.667S^0.5 Flow using average channel slope of 0.0073ft/ft:
AREA = 21.14 ft2. WP = 13.73 ft. R = 1.54 ft. (CAD).

n = 0.035 Q = 102 cfs These bankfull flows seem quite high.
n= 0.040 Q = 90 cfs
n = 0.045 Q = 80 cfs

ASSUME the Qbkf Elevation of 5023.04 is accurate as estimated in the field. Bankfull Width = 7.7 feet (CAD section).

RETURN INTERVAL	Basin Characteristics		6' Active Channel Width		8' Active Channel Width		Weighted-Basin Characteristics & 7.7' Bankfull Channel Width	
	Flow (cfs)	SEP (%)	Flow (cfs)	SEP (%)	Flow (cfs)	SEP (%)	Flow (cfs)	SEP (%)
Q2							31	58.1
Q5							73	52.7
Q10							118	55.1
Q25							197	60.2
Q50							270	64.6
Q100							355	69.1
Estimated Bankfull Flow (cfs)								
Q_{bkf}							20	

Manning's: Q=A(1.486/n)R^0.667S^0.5:

AREA = 6.58 ft2. WP = 8.5 ft. R = 0.774 ft. (CAD).

The estimated bankfull slope using visual indicators was 0.0025. It should be noted that these were hard to determine visually in the field.

The average channel slope from the 9-22-2015 survey was 0.0073 ft/ft.

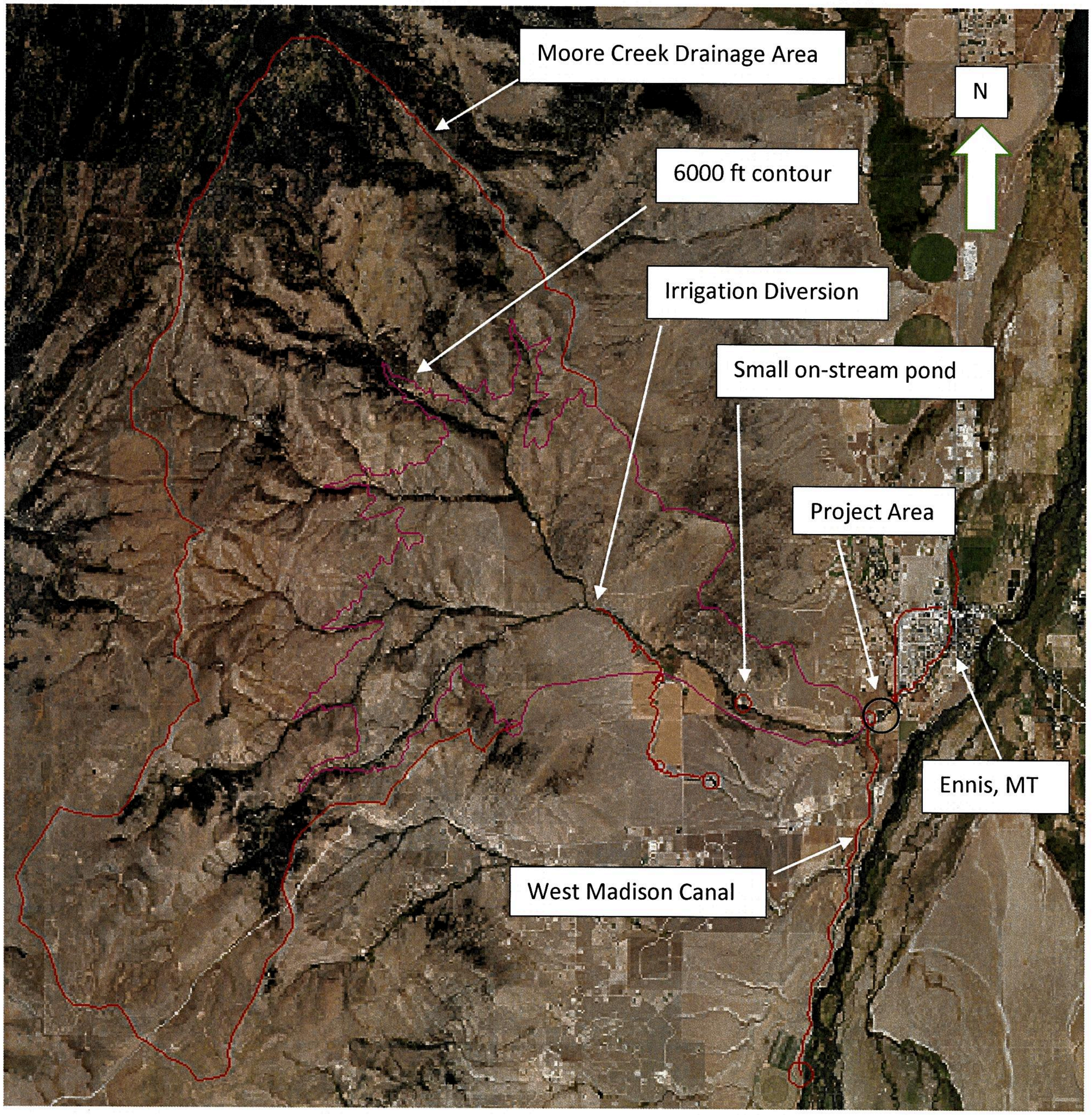
	s=0.0025 ft/ft	s = 0.0073 ft/ft
n = 0.035	Q = 11.8 cfs	Q = 20.1 cfs
n= 0.040	Q = 10.3 cfs	Q = 17.6 cfs
n = 0.045	Q = 9.2 cfs	Q = 15.6 cfs

$Q_{bkf} = Q2(Q2/Q5)^{0.52}$.

Base flow estimate 2-4 cfs.

David Lyons-Moore Creek:

Drainage Area = 30 square miles Drainage Area above 6000 feet = 20.92 square miles (69.8%).



Computation Sheet

NRCS–ENG-523A Rev. 6-2002

U.S. Department of Agriculture
Natural Resources Conservation Service

State	Project		
MT	David Lyons		
By: MWZ	Date: 9/15	Checked by:	Date:	Job No.:
Subject: Estimated Culvert Flow w/ water Mark		Sheet 1 of 2	

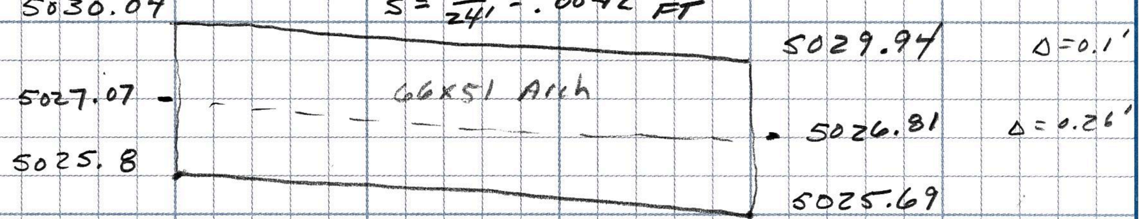
Culvert Field Measurements: Rise (D) = 4.7' = 56.4"
Span (B) = 5.4' = 64.8"

use 66" x 51" (standard size)

Top Culvert Inlet = 5030.04   Inlet WS ≅ 5027.07
Top culvert outlet = 5029.94   outlet WS ≅ 5026.81

Culvert Length = 24 FT

$S = \frac{0.1'}{24'} = .0042 \frac{FT}{FT}$



Flow depth 1.27'   Flow depth 1.12'

Avg depth ≅ 1.2' = d

$\frac{d}{D} = \frac{1.2'}{4.25} = 0.28$ $n \doteq .024$

Table 6 $\frac{A}{BD} = .237$ $A = .237(66")(51") = 797.7\ in^2 = 5.54\ FT^2$

Table 7 $\frac{R}{D} = .204$ $R = .204(51") = 10.4" = 0.867\ FT$

$$Q = A \frac{1.486}{n} R^{2/3} S^{1/2}$$

$$= 5.54 \frac{(1.486)}{.024} (.867)^{2/3} (.0042)^{1/2}$$

$$= \underline{\underline{20.21}}\ CFS$$

HYDRAULIC PROPERTIES OF PIPE ARCH FLOWING PART FULL

Table 6
Determination of Area — Values of $\frac{A}{BD}$

A: factor (BD)

$\frac{d}{D}$	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.1		.072	.081	.090	.100	.109	.119	.128	.138	.148
.2	.157	.167	.177	.187	.197	.207	.217	.227	.237	.247
.3	.257	.267	.277	.287	.297	.307	.316	.326	.336	.346
.4	.356	.365	.375	.385	.394	.404	.413	.423	.432	.442
.5	.451	.460	.470	.479	.488	.497	.506	.515	.524	.533
.6	.541	.550	.559	.567	.576	.584	.592	.600	.608	.616
.7	.624	.632	.640	.647	.655	.662	.670	.677	.684	.690
.8	.697	.704	.710	.716	.722	.728	.734	.740	.745	.750
.9	.755	.760	.764	.769	.772	.776	.780	.783	.785	.787
1.0	.788									

d = Depth of flow
D = Rise of conduit
B = Span of conduit
A = Area of flow
R = Hydraulic radius
T = Top width of flow

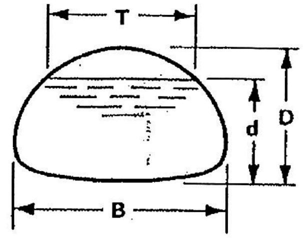


Table 7
Determination of Hydraulic Radius — Values of $\frac{R}{D}$

$\frac{d}{D}$	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.1		.078	.086	.094	.102	.110	.118	.126	.133	.141
.2	.148	.156	.163	.170	.177	.184	.191	.197	.204	.210
.3	.216	.222	.228	.234	.240	.245	.250	.256	.261	.266
.4	.271	.275	.280	.284	.289	.293	.297	.301	.305	.308
.5	.312	.315	.319	.322	.325	.328	.331	.334	.337	.339
.6	.342	.344	.346	.348	.350	.352	.354	.355	.357	.358
.7	.360	.361	.362	.363	.363	.364	.364	.365	.365	.365
.8	.365	.365	.364	.364	.363	.362	.361	.360	.359	.357
.9	.355	.353	.350	.348	.344	.341	.337	.332	.326	.318
1.0	.299									

Table 8
Determination of Top Width — Values of $\frac{T}{B}$

$\frac{d}{D}$	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.1		.900	.914	.927	.938	.948	.956	.964	.971	.976
.2	.982	.986	.990	.993	.995	.997	.998	.998	.998	.999
.3	.997	.996	.995	.993	.991	.989	.987	.985	.982	.979
.4	.976	.971	.967	.964	.960	.956	.951	.947	.942	.937
.5	.932	.927	.921	.916	.910	.904	.897	.891	.884	.877
.6	.870	.863	.855	.847	.839	.830	.822	.813	.803	.794
.7	.784	.773	.763	.752	.741	.729	.717	.704	.691	.678
.8	.664	.649	.634	.618	.602	.585	.567	.548	.528	.508
.9	.486	.462	.437	.410	.381	.349	.313	.272	.223	.158

HYDRAULIC PROPERTIES CIRCULAR CONDUITS FLOWING PART FULL

Table 9
Determination of Area — Values of $\frac{A}{D^2}$

$\frac{d}{D}$	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.000	.001	.004	.007	.011	.015	.019	.024	.029	.035
.1	.041	.047	.053	.060	.067	.074	.081	.089	.096	.104
.2	.112	.120	.128	.136	.145	.154	.162	.171	.180	.189
.3	.198	.207	.217	.226	.236	.245	.255	.264	.274	.284
.4	.293	.303	.313	.323	.333	.343	.353	.363	.373	.383
.5	.393	.403	.413	.423	.433	.443	.453	.462	.472	.482
.6	.492	.502	.512	.521	.531	.540	.550	.559	.569	.578
.7	.587	.596	.605	.614	.623	.632	.640	.649	.657	.666
.8	.674	.681	.689	.697	.704	.712	.719	.725	.732	.738
.9	.745	.750	.756	.761	.766	.771	.775	.779	.782	.784
1.0	.785									

D = Diameter
d = Depth of Flow
A = Area of Flow
R = Hydraulic Radius
T = Top Width

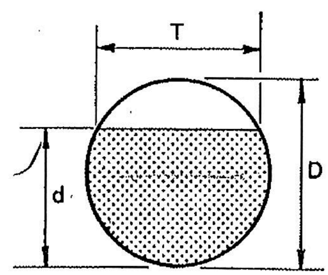


Table 10
Determination of Hydraulic Radius — Values of $\frac{R}{D}$

$\frac{d}{D}$	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.000	.007	.013	.020	.026	.033	.039	.045	.051	.057
.1	.063	.070	.075	.081	.087	.093	.099	.104	.110	.115
.2	.121	.126	.131	.136	.142	.147	.152	.157	.161	.166
.3	.171	.176	.180	.185	.189	.193	.198	.202	.206	.210
.4	.214	.218	.222	.226	.229	.233	.236	.240	.243	.247
.5	.250	.253	.256	.259	.262	.265	.268	.270	.273	.275
.6	.278	.280	.282	.284	.286	.288	.290	.292	.293	.295
.7	.296	.298	.299	.300	.301	.302	.302	.303	.304	.304
.8	.304	.304	.304	.304	.304	.303	.303	.302	.301	.299
.9	.298	.296	.294	.292	.289	.286	.283	.279	.274	.267
1.0	.250									

Table 11
Determination of Top Width — Values of $\frac{T}{D}$

$\frac{d}{D}$	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.000	.199	.280	.341	.392	.436	.457	.510	.543	.572
.1	.600	.626	.650	.673	.694	.714	.733	.751	.768	.785
.2	.800	.815	.828	.842	.854	.866	.877	.888	.898	.908
.3	.917	.925	.933	.940	.947	.954	.960	.966	.971	.975
.4	.980	.984	.987	.990	.993	.995	.997	.998	.999	1.000
.5	1.000	1.000	.999	.998	.997	.995	.993	.990	.987	.984
.6	.980	.975	.971	.966	.960	.954	.947	.940	.933	.925
.7	.917	.908	.898	.888	.877	.866	.854	.842	.828	.815
.8	.800	.785	.768	.751	.733	.714	.694	.673	.650	.626
.9	.600	.572	.543	.510	.475	.436	.392	.341	.280	.199
1.0	.000									

i.e. Given d = 3 ft., D = 4 ft., $\frac{d}{D} = 0.75$,

From Tables; $\frac{A}{D^2} = 0.632$, $\frac{R}{D} = 0.30$, and $\frac{T}{D} = 0.866$

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